GEOPHYSICAL CHARACTERIZATION OF THE CAMP ROBERTS LANDFILL USING INNOVATIVE HARDWARE AND SOFTWARE TOOLS

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Camp Roberts Background

- Located about 35 miles north of San Luis Obispo, California
- Built in 1941-42 as an Army base
- Now under direction of the California National Guard
- Includes a 14.2-acre permitted landfill and a historic landfill area of undetermined size

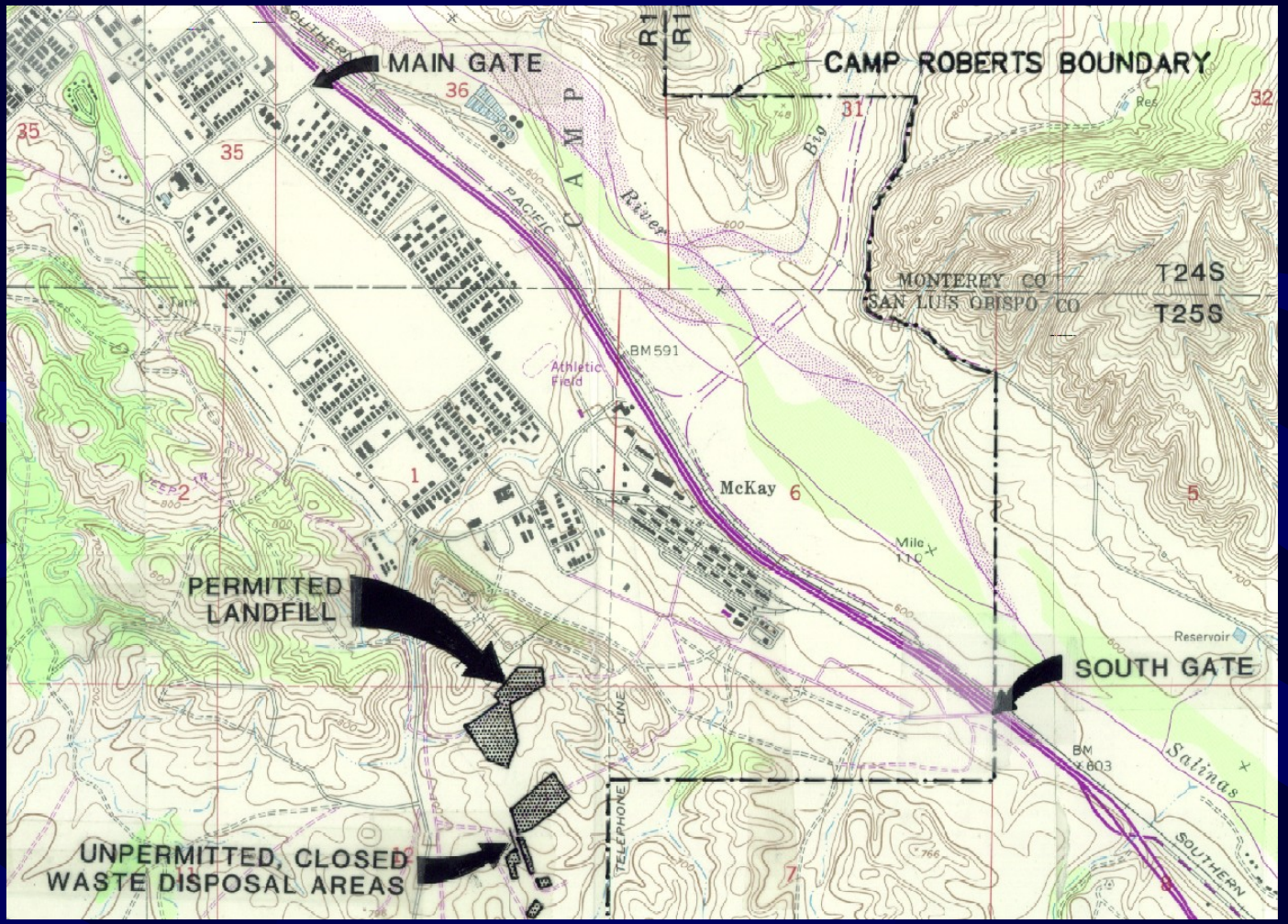
Camp Roberts Background (cont.)

- Remediation alternatives hinge on determining whether the two landfills are connected
- Historic landfill area includes at least five mapped disposal areas
- Surficial geology composed of Cenezoic non-marine sedimentary deposits, including clays and clastic sediments
- Water table at about 100 ft depth
- Bedrock depth unknown

Geophysical Survey Objectives

- Define boundaries of active and historic landfills
- Conduct depth profiling to define geologic setting and landfill areas
- Determine relative effectiveness of new and conventional geophysical methods at this site
- Identify other relevant geologic features (e.g. water table, bedrock) where possible

Map View of the Landfill and Surrounding

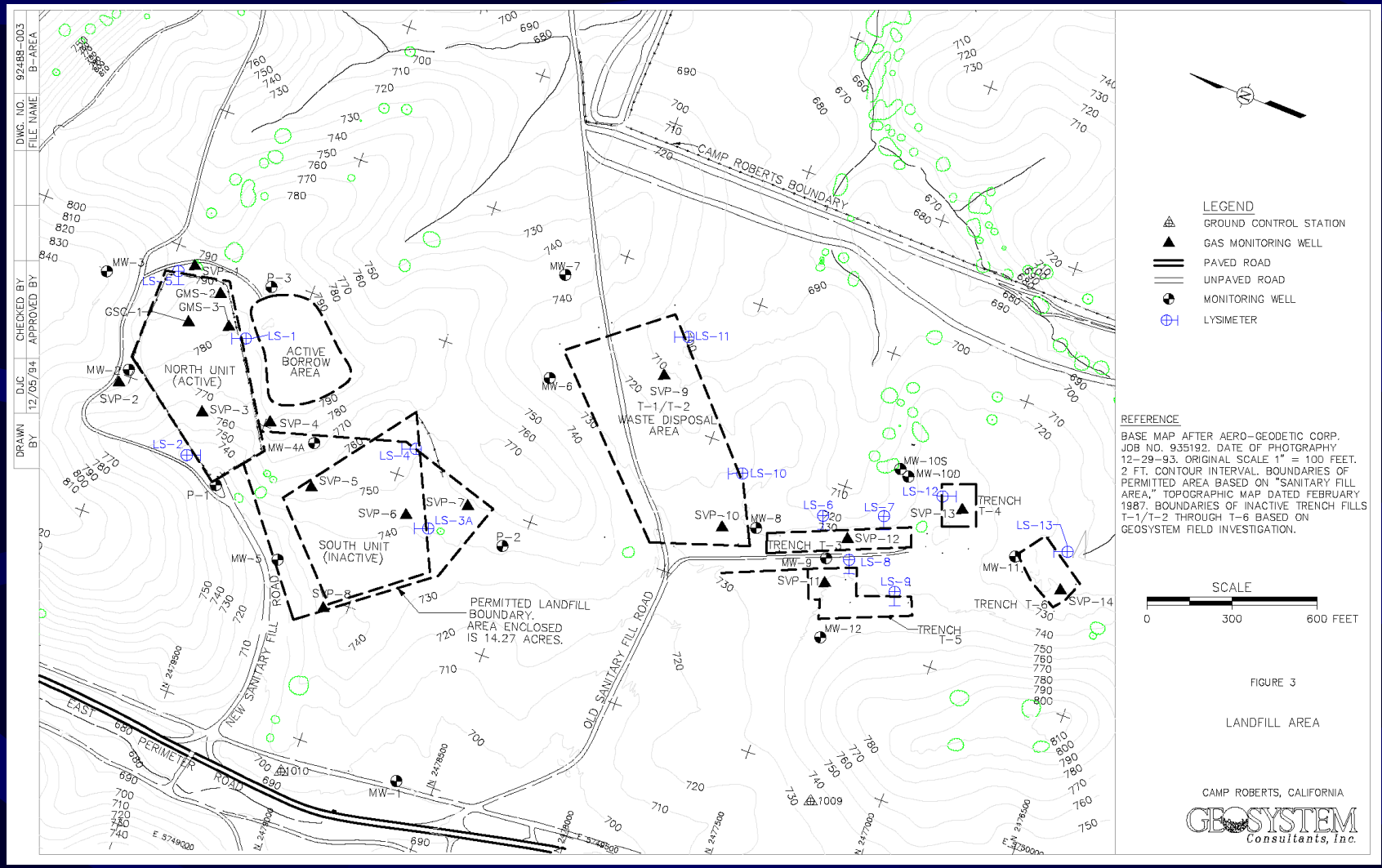


From Geosystems, Inc., 1998

Active Landfill

Historic Landfil

Pre-survey evaluation of trench Locati

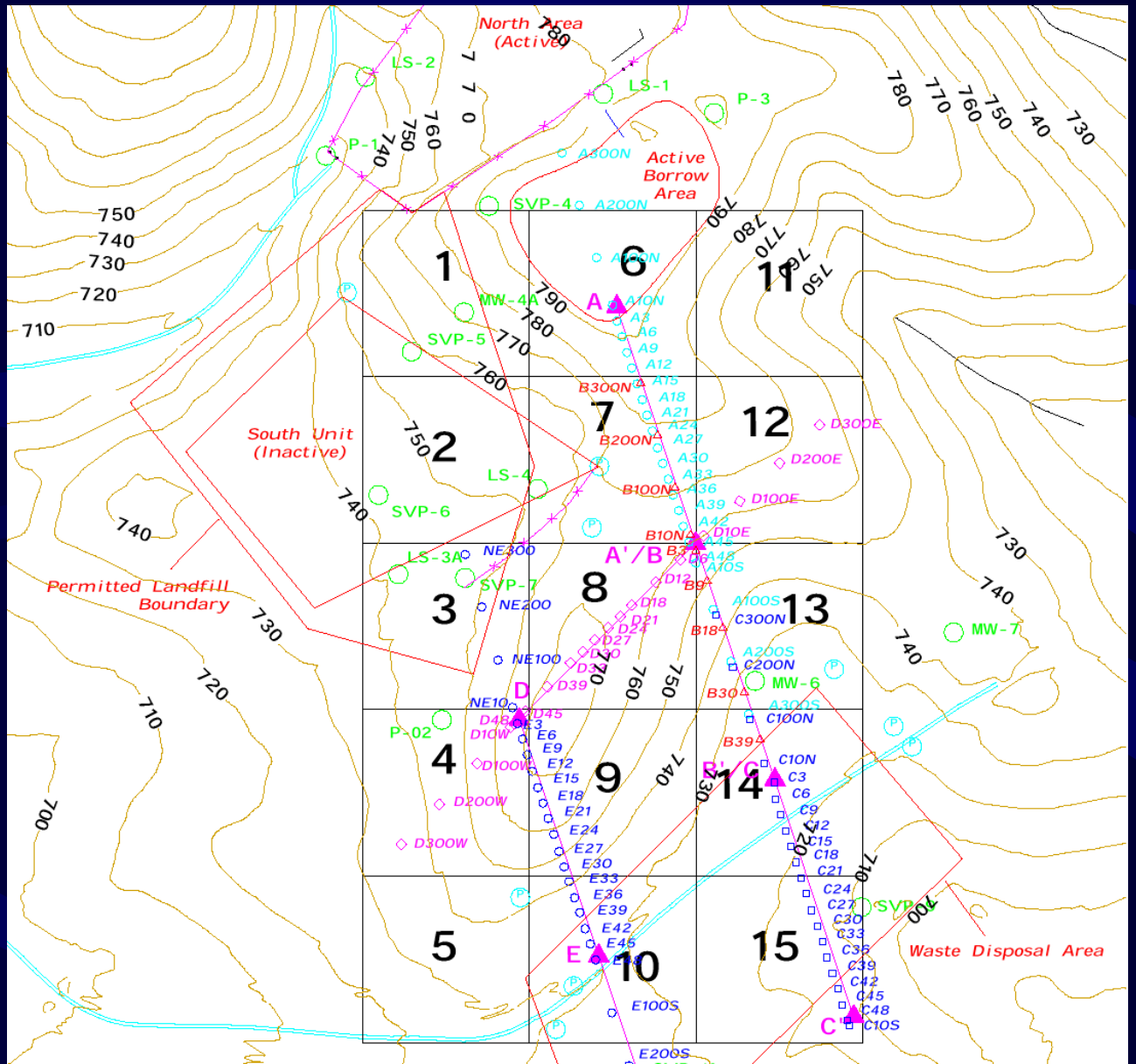


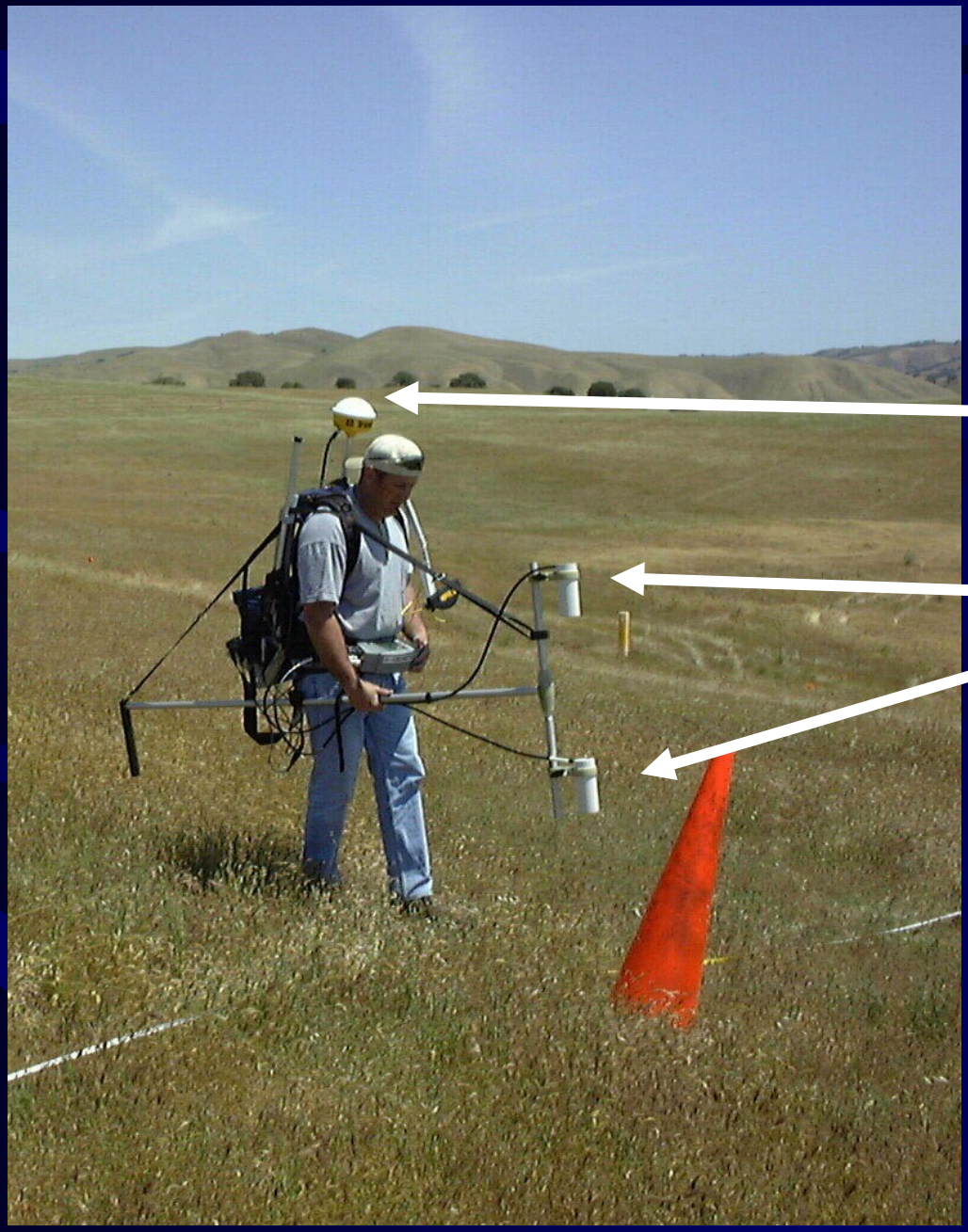
From Geosystems, Inc., 1998

Technologies Deployed

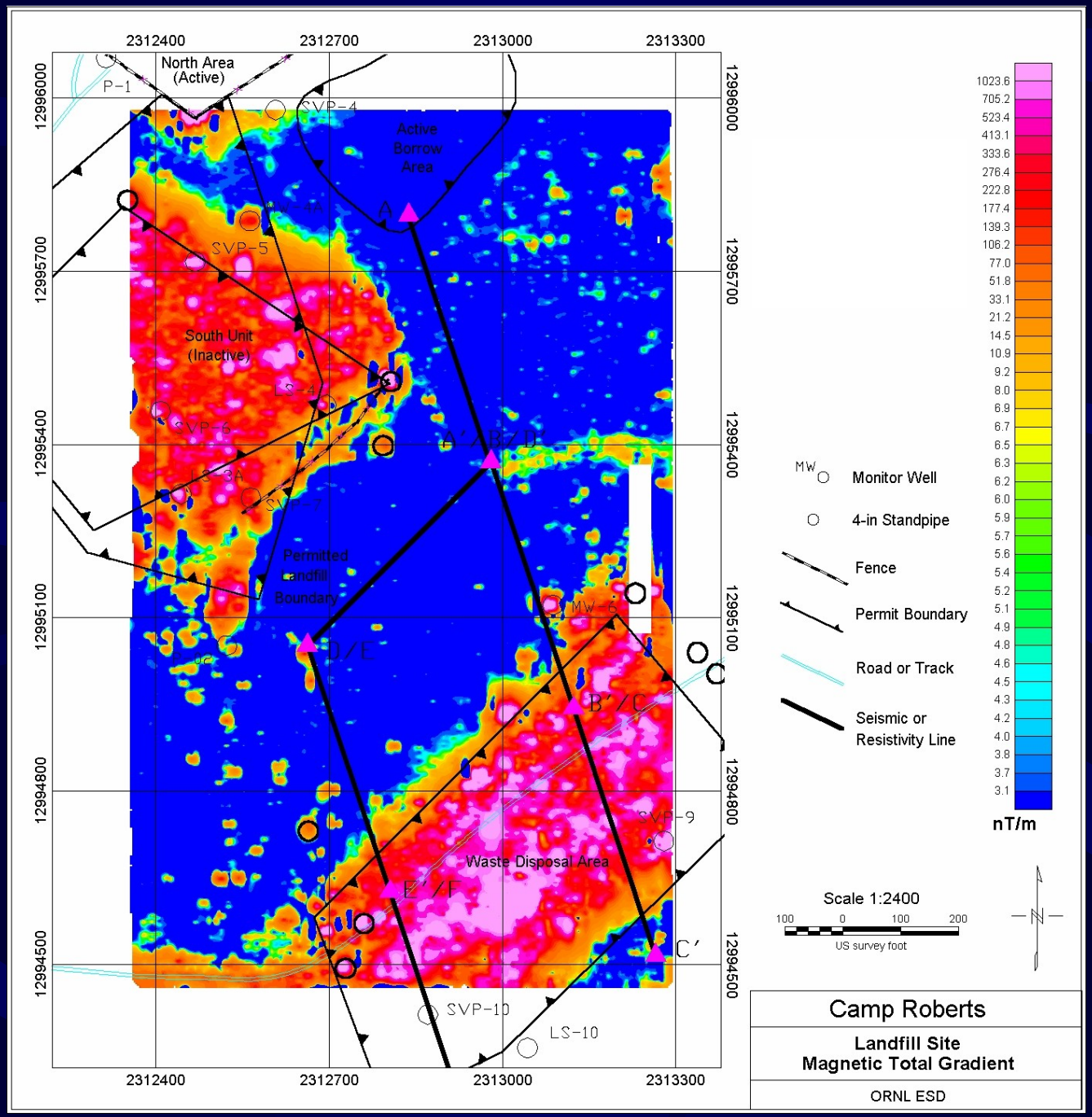
- Magnetic gradient mapping over region between active and inactive landfills
- Electromagnetic (EM61) mapping over selected quadrant
- Multielectrode resistivity profiling
- Capacitively-coupled resistivity
- Conventional and tomographic seismic refraction profiling

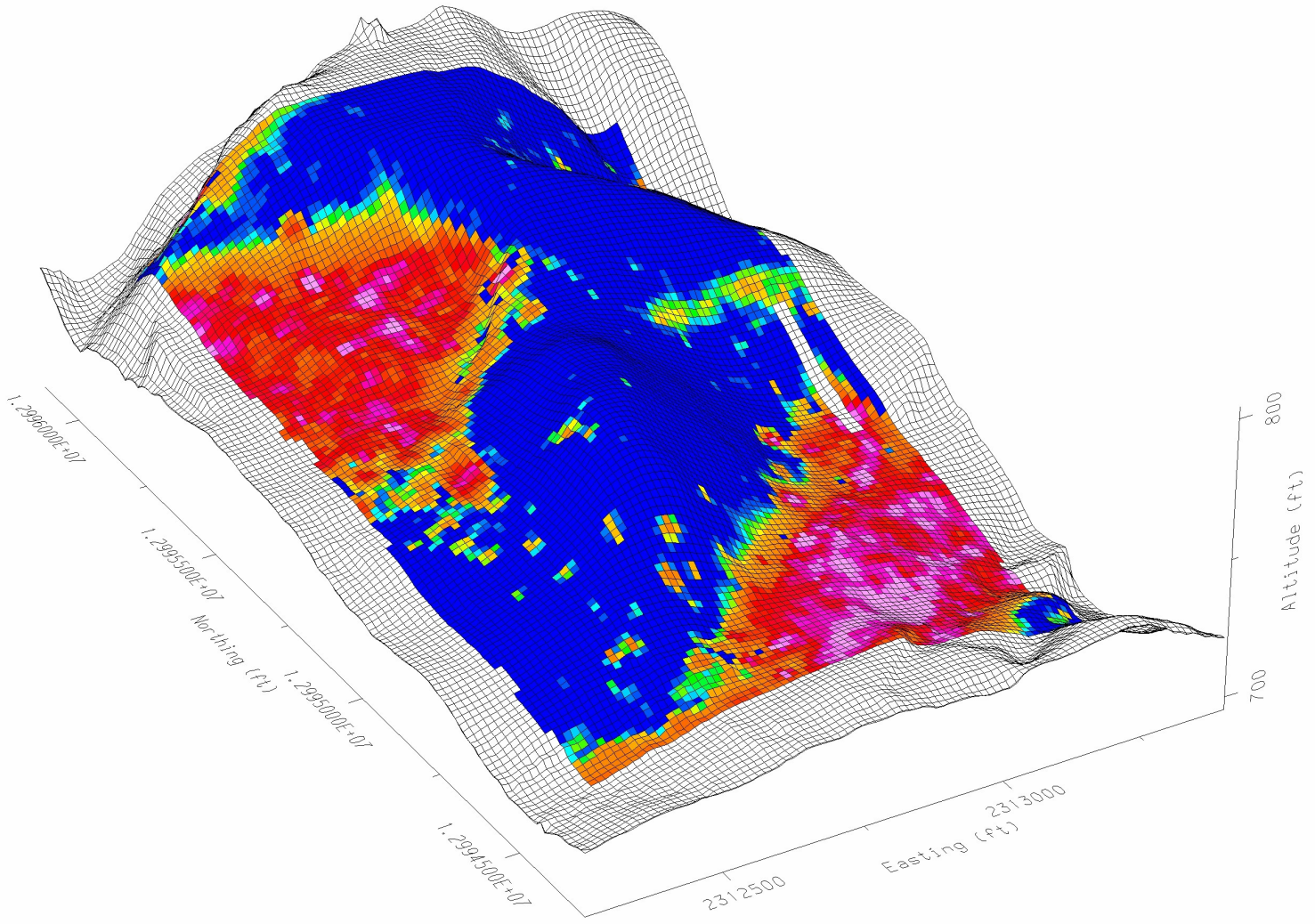
Quadrants and Profiles in Area of Investi





Magnetic Gradiometer Survey


2312400
2312700
2313000
2313300
12996000
12995700
12995400
12995100
12994800
12994500
North Area
(Active)
P-1
SVP-4
Active
Borrow
Area
A
SVP-5
South Unit
(Inactive)
LS-4
SVP-6
A′/B/D
LS-3A
SVP-7
Permitted
Landfill
Boundary
MW-6
D/E
B′/C
SVP-9
Waste Disposal Area
E′/F
C′
SVP-10
LS-10
1023.6
705.2
523.4
413.1
333.6
276.4
222.8
177.4
139.3
106.2
77.0
51.8
33.1
21.2
14.5
10.9
9.2
8.0
6.9
6.7
6.5
6.3
6.2
6.0
5.9
5.7
5.6
5.4
5.2
5.1
4.9
4.8
4.6
4.5
4.3
4.2
4.0
3.8
3.7
3.1
nT/m
MW
Monitor Well
4-in Standpipe
Fence
Permit Boundary
Road or Track
Seismic or
Resistivity Line
Scale 1:2400
100
0
100
200
US survey foot
N
Camp Roberts
Landfill Site
Magnetic Total Gradient
ORNL ESD



Total Magnetic Field Map Draped over 3-D Topo

Magnetic Survey Results

- Historic and Active Landfills clearly separated
- Clear definition of trench boundaries
- Boundaries differ slightly from previous maps
- A few small anomalies may warrant follow-on investigation

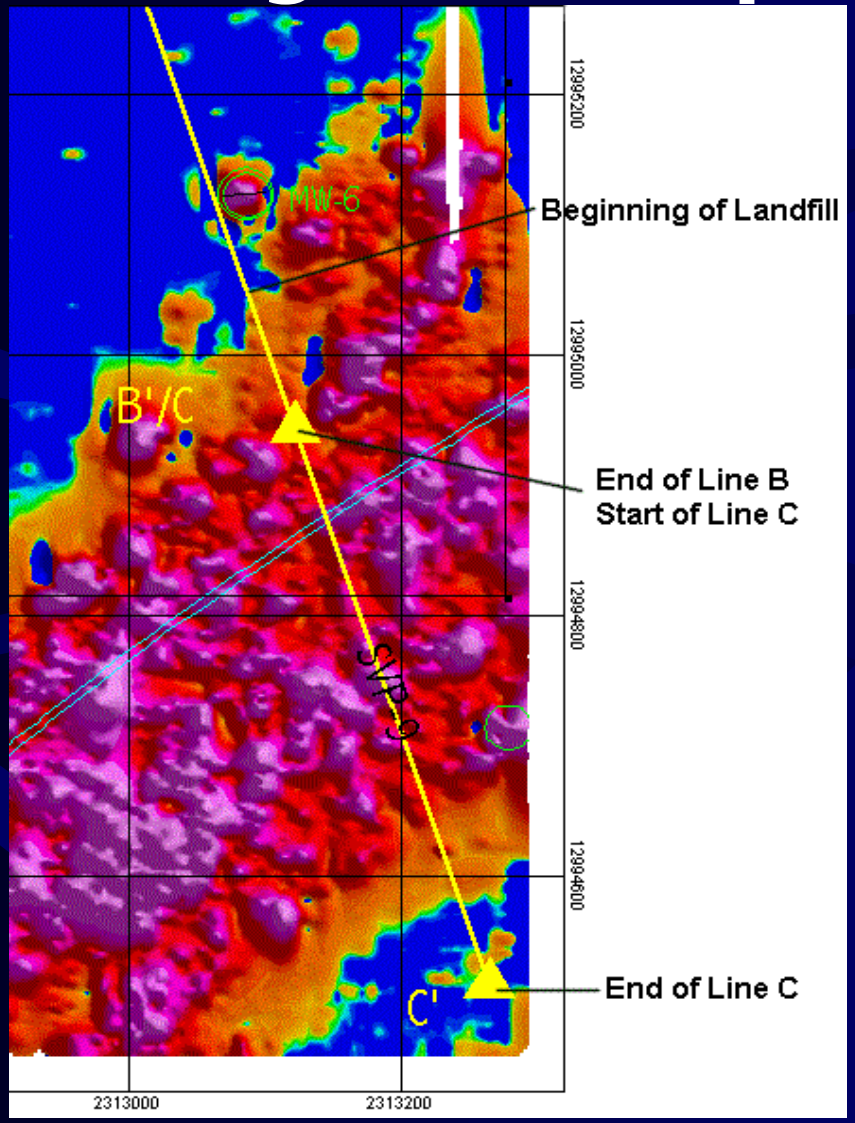
Multielectrode Resistivity Method

- Provides a cross sectional view
- Uses multiprocessor controlled switching box to activate pre-selected current and potential electrode pairs
- Less susceptible to surface interference than many electromagnetic methods

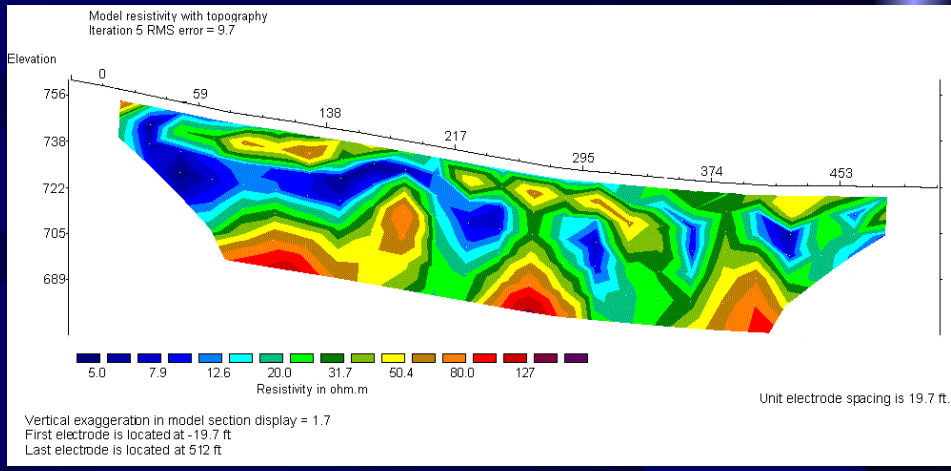
Multielectrode Resistivity Survey Operatio

Multielectrode Resistivity Survey

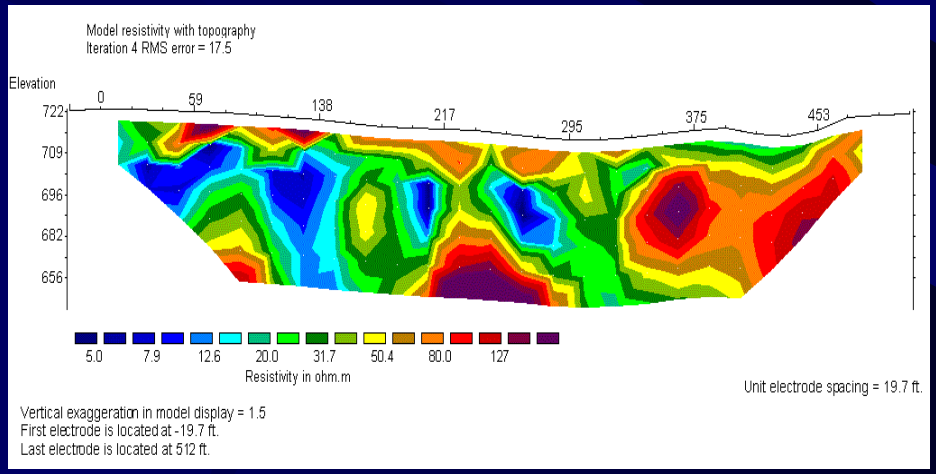
Magnetic Map



Line B



Line C



Multielectrode Resistivity Results

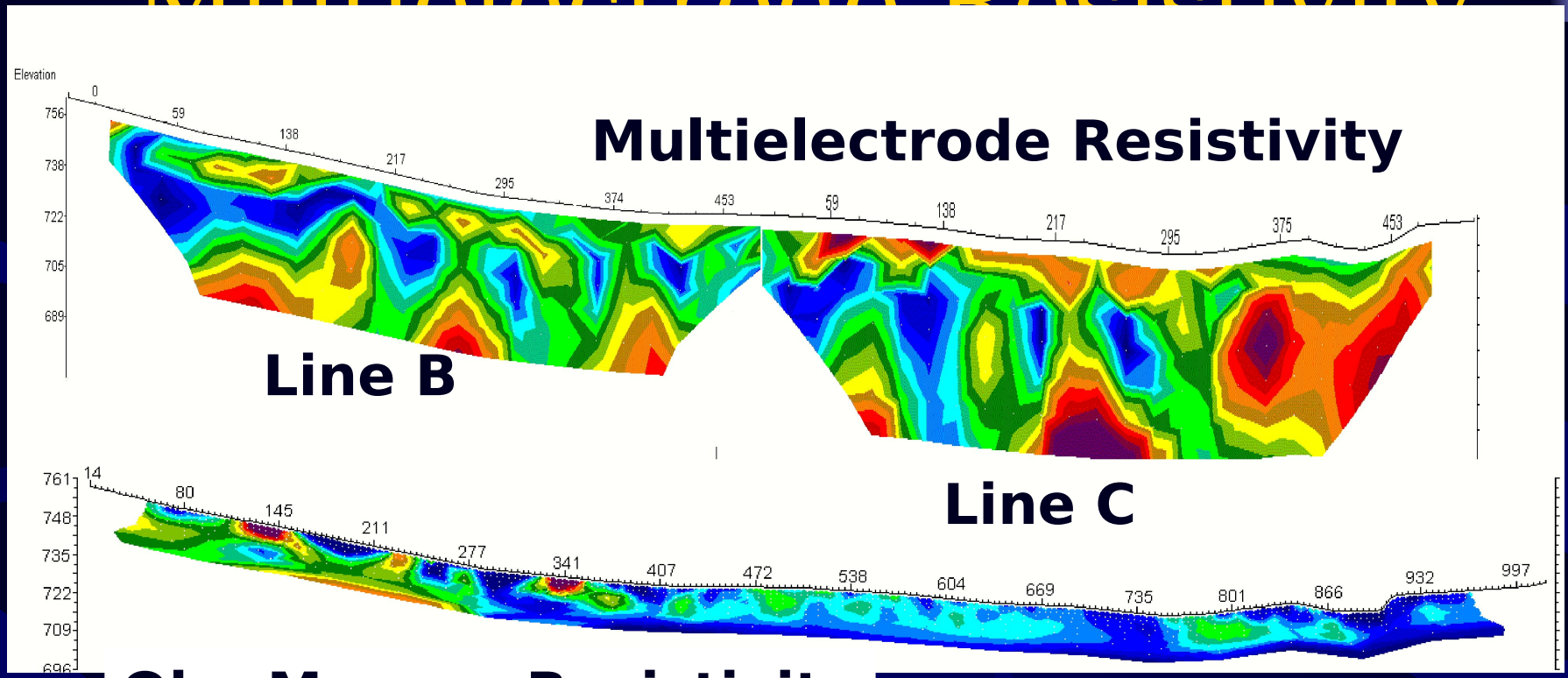
- Low surface resistivities (< 200 ohm-m), due to clays and/or evaporites
- Penetration is limited to about 50 ft. by these resistivities
- Layering is disrupted in landfill areas
- Buried metals difficult to distinguish, as they are masked by conductive geology

OhmMapper Resistivity System

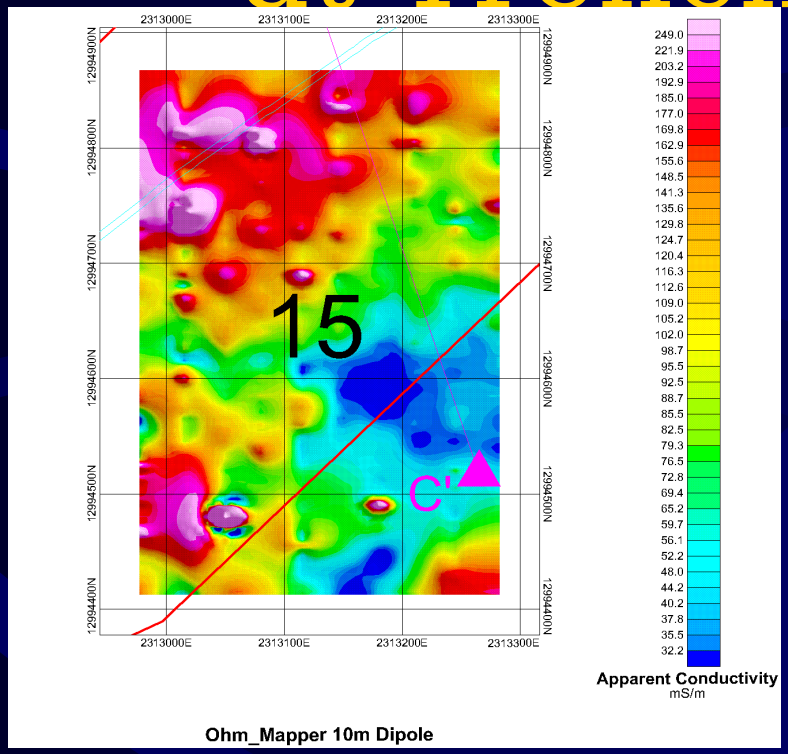
- Capacitively-coupled system requires no electrodes in the ground or coil transmitters
- Can be used to produce depth profiles or maps
- Acquisition is faster than resistivity methods
- Most appropriate where the near-surface is resistive

OhmMapper System

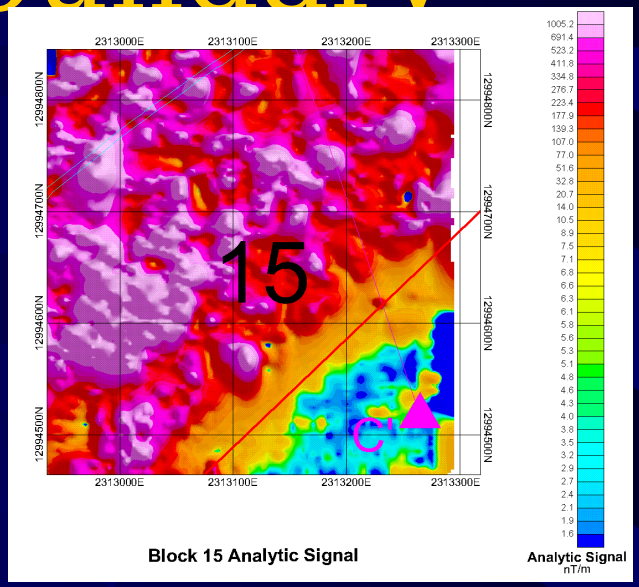
Comparison of OhmMapper with Multielectrode Resistivity



Comparison of OhmMapper Resistivity with Magnetic Results at Trench Boundary



OhmMapper Conductivity



Magnetic Analytic Signal

Results of OhmMapper test

- Identifies a conductivity increase at trench boundary, probably due to buried metal
- Higher horizontal resolution than multielectrode system
- Penetration was inhibited by conducting surface layer
- Surveying was much quicker with OhmMapper than multielectrode system
- OhmMapper is a good choice for mapping or profiling where surface is resistive

Seismic Refraction Profiling

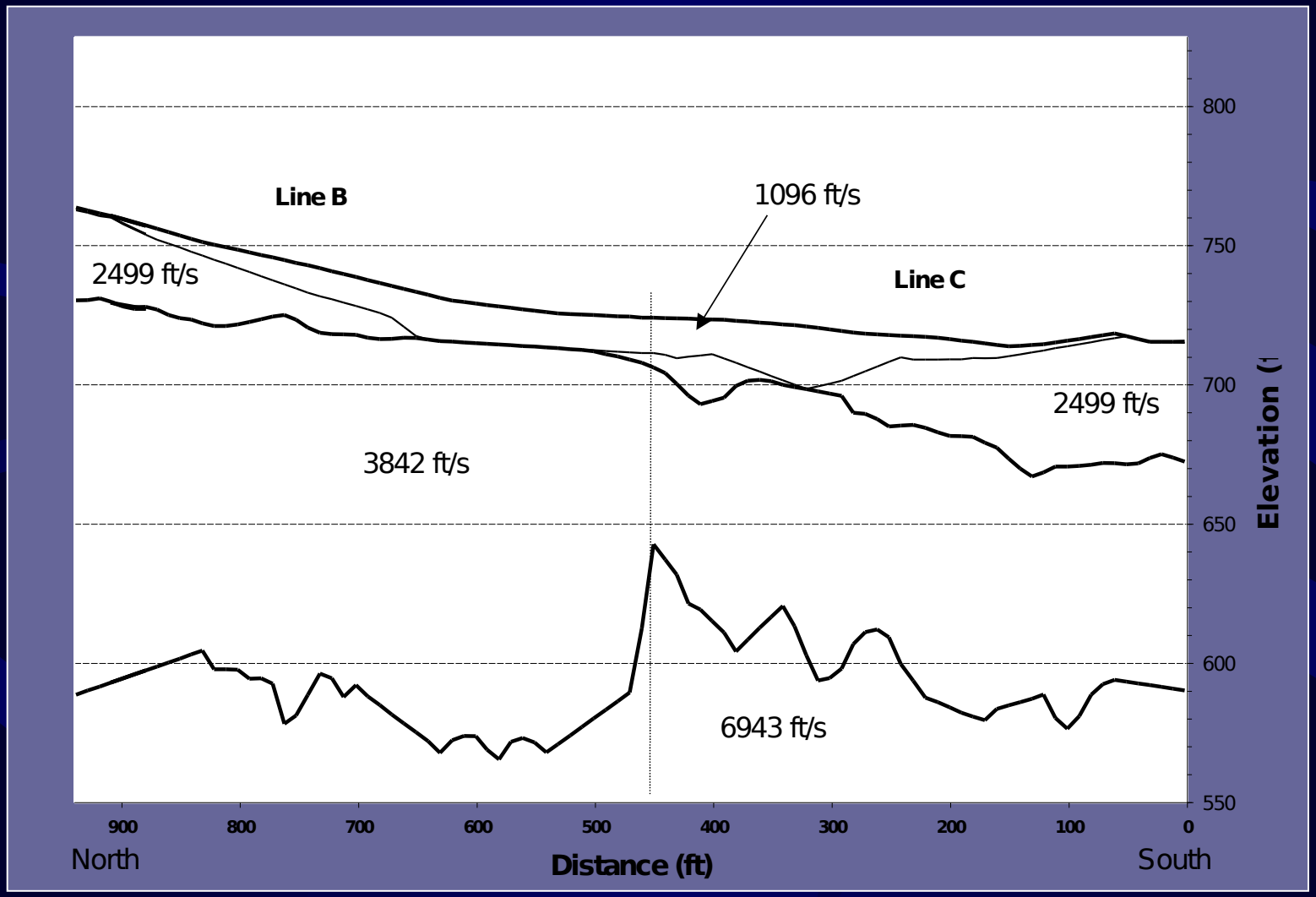
Conventional Seismic Refraction Profiling

- Conventional time-delay method assumes continuous, constant-velocity layers
- Lateral changes in velocity are generally observed as a thickening or thinning of bounding layers; deeper boundaries are often disrupted
- Typically used for bedrock determination rather than mapping lateral transition into a landfill.
- Assume that velocity always increases with depth

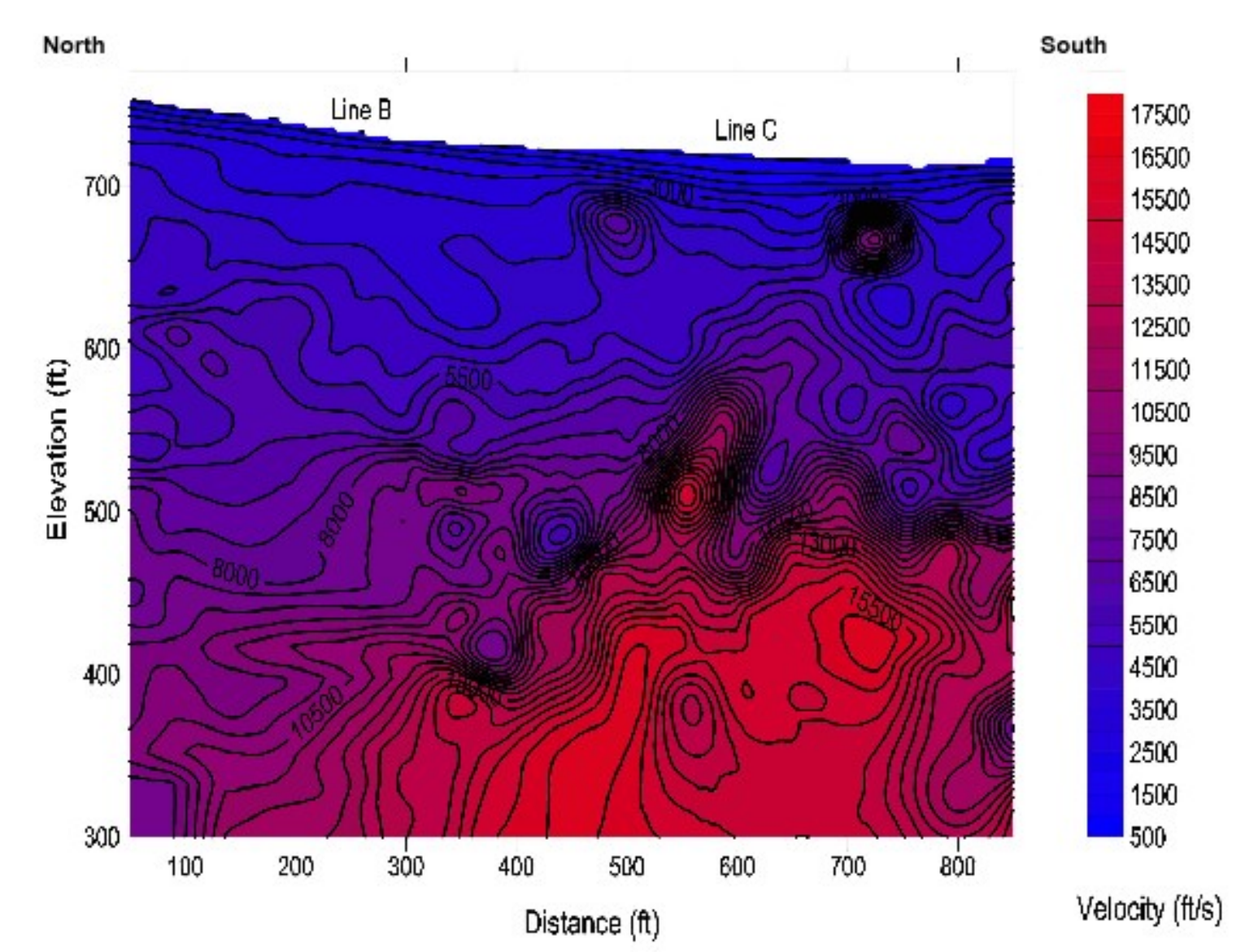
Tomographic Seismic Refraction Inversion

- Requires more shot points (at least every third geophone + off-end shots)
- Allows velocities to change laterally and vertically
- Allows gradational changes in velocity
- Permits mapping of velocities within a landfill in addition to bedrock mapping

Conventional (Time Delay) Result for Lines B and C



Tomographic Result for Lines B and C



Seismic Refraction Results

- Raw data show a clear gradient in velocity which cannot be adequately modeled with conventional time-delay methods
- Lateral changes in velocity are also apparent in the raw data
- Tomographic inversion shows a more acceptable result, including high velocity zones within the trench area

Summary

- GPS-controlled magnetometer is best suited for producing maps of landfills of this size
- Profiles may be acquired by seismic or resistivity methods
- Multielectrode resistivity has greater penetration than capacitive systems where surface conductivity is high

Summary (continued)

- Capacitive systems would be favored for resistivity profiling non-conductive environments because data can be acquired more rapidly
- Tomographic seismic refraction inversion allows mapping of landfill boundaries where time-delay methods fall short
- These same non-invasive methods are suitable for a wide range of near-surface characterization problems